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Accident Dosimetry by Thermoluminescence of Feldspar

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Several crystals of natural feldspar were surveyed for the purpose of accident dosimetry by thermoluminescence. The glow curves resulting from the samples showed glow peaks at about 140°C, 170°C and 230°C. It has been found that the 140°C peak is the most desirable one from a view-point of accident dosimetry. About this glow peak, the natural glow intensity and sensitivity were examined over some microcline samples. Moreover, the variations of glow curve with the ^{60}Co gamma-ray doses were observed on the two samples and it was assured that the 140°C peak had the advantage of excellent linearity for the absorbed dose to 5×10^4r at least.

I. INTRODUCTION

As previously described,[1,2] natural quartz and feldspar were chosen as dosimeter for radiation accidents which occurred at unexpected place, since they are the ordinary substances found abundantly on the ground. The samples used in the last experiment were separated from sands and soil by means of a magnetic method and selective staining method. Comparing the thermoluminescence properties of the two samples, we concluded that feldspar fraction was more useful than quartz fraction as a phosphor for accident dosimetry, because of its high sensitivity for the absorbed dose.

In the present investigation various crystals of feldspar (K-feldspar, Na-feldspar and Ca-feldspar) were examined from the standpoint of accident dosimetry. The 140°C peak, which is the most desirable one for the estimation of the accident dose, is reported in detail about its thermoluminescence properties, such as sensitivity, linearity and fading.

II. MATERIAL AND METHODS

The crystals were ground with an agate mortar and pestle and then the grains were sieved so that size distributions of 100 to 200 mesh were obtained. The apparatus used for measurement consisted of a furnance with a silver hot plate, a photomultiplier (Toshiba 7696) of 2″ in diameter, a D. C. amplifier (2×10^{-4} $\sim3\times10^{-13}$A), and a two-pen recorder. The hot plate on which the powder sample (300 mg) was spread evenly was equipped with a chromel-alumel thermocouple. The heating rate was about 75°C/min until the temperature reached 450°C. A Co^{60} gamma-irradiation facility which belongs to the Institute for Chemical Research of Kyoto University was used for the irradiation of the sample.

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The materials used for measurement were microcline (I, II, and III), andesine, albite (I and II), bytownite, oligoclase and labradorite. Feldspars of the different places of production were prepared for microcline and albite.

III. RESULTS

1) Glow Curves of Various Feldspars

The typical glow curves of natural feldspar, (K-feldspar, Na-feldspar and Ca-feldspar) are shown in Figs. 1, 2, and 3. Since natural crystals have received, over a long period, radiation coming from some radioactive elements contained in themselves and other natural radiation from the outside, the crystals show glow signal when it is heated. As a common trend of natural glow curves of feldspar, the samples exhibit generally the glow maximum at about 220°C. The identical results were also obtained with the glow curves for feldspar separated from sands, as previously described.[3] The glow maximum at the low temperature region is extremely low in intensity as compared with the case of artificial irradiation. The low temperature glow peak corresponds to electrons in shallow traps, whose life time is rather short, so that the peak has decayed out for the most part at ambient temperature, while the high temperature peak has decayed out partially.

Recordings of the glow curves for feldspar irradiated by the known amount of ^{60}Co gamma rays are also shown in Figs. 1, 2 and 3. As compared with the natural glow curves, the enhancement of the glow peak at 140°C can especially

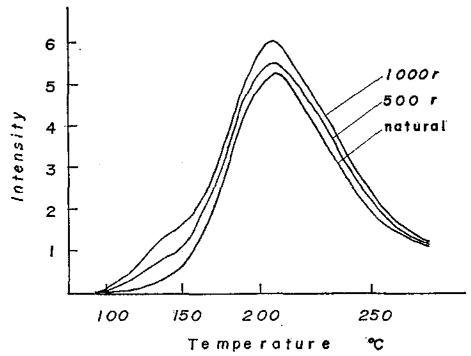

Fig. 1. Glow curve recording of microcline III (K-feldspar).

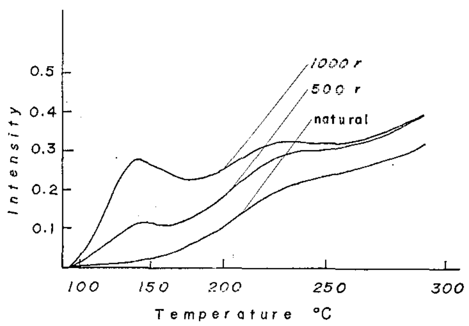

Fig. 2. Glow curve recording of albite II (Na-feldspar).

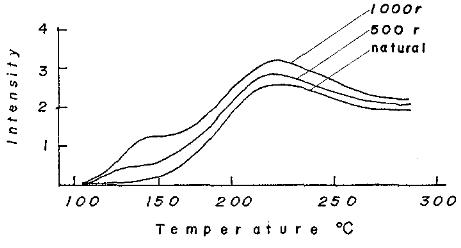

Fig. 3. Glow curve recording of oligoclase (Ca-feldspar).

Table 1. Sensitivity and intensity of the natural background for the 140°C peak of various samples.

Material	Ampere (A)/Dose (r) ($\times 10^{-10}$)	Intensity of natural background (r)
Microcline I	2.8	54
Microcline II	1.13	18
Microcline III	1.0	300
Andesine	0.88	261
Albite I	17.0	86
Albite II	0.25	4
Oligoclase	1.1	44
Labradorite	0.009	220
Feldspar of sand I	6.4	600
Quartz of sand I	6.145	241
Feldspar of sand II	1.6	250
Quartz of sand II	0.15	445

be recognized in the case of artificial irradiation. When the samples are exposed to radiation from a nuclear accident, the glow curves are generally complicated by overlapping of the two glow curves, one of which is natural glow curve and the other is due to the accident radiation. Generally, the area under the glow peak should be used as a measure of dose in thermoluminescent dosimetry. Accordingly, one essential condition for the glow peak to be used is that the glow intensity is nearly zero prior to the radiation accident, and the background signal which has been caused by the natural radition over a long period will restrict the accident dosimetry. In view of this fact, the 140°C peak is more desirable peak than the other peaks at the higher temperature region, since the decay of the 140°C peak due to ambient temperatre is large as compared to that of the other peaks. The intensity of the background signal, *i. e.*, the peak height of the 140°C peak, can be obtained by comparing the glow signal resulting from the known amount of irradiation of ^{60}C gamma rays. The equivalent

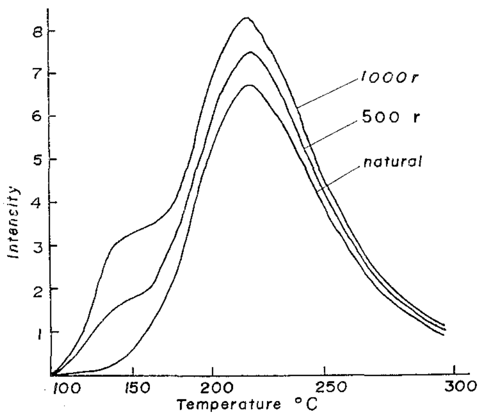

Fig. 4. Glow curves for microcline I irradiated with gamma rays. (500 r and 1000 r).

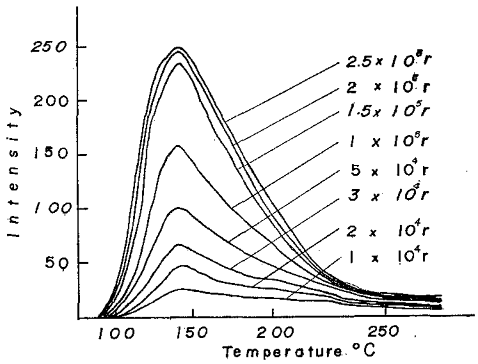

Fig. 5. Glow curves for microcline I irradiated with gamma rays. ($1\times10^{4}\sim2.5\times10^{5}$ r).

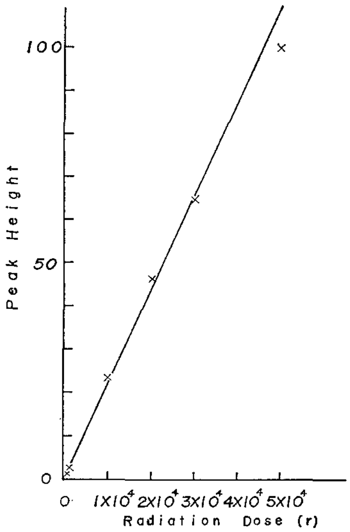

Fig. 6. Variation of the 140°C peak height of microcline I for various doses. ($500 \sim 5 \times 10^4$ r)

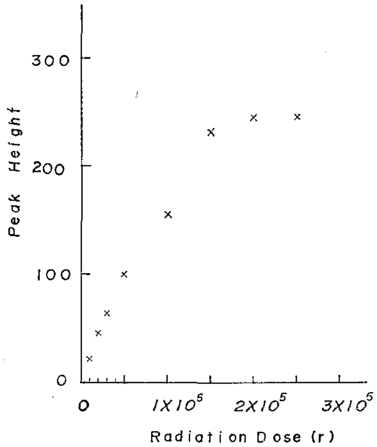

Fig. 7. Variation of the 140°C peak height of microcline I for various doses. ($1 \times 10^4 \sim 2.5 \times 10^5$ r).

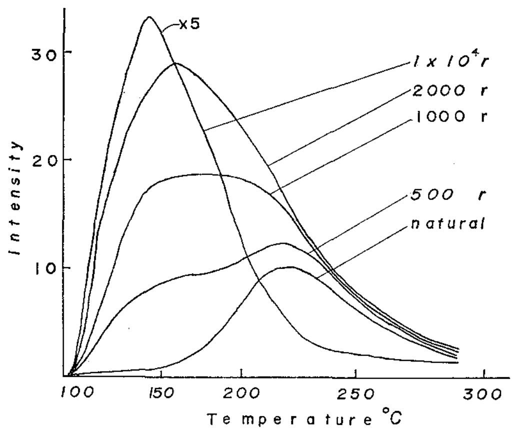

Fig. 8. Glow curves for albite I irradiated with gamma rays. ($500 \sim 1 \times 10^4$ r)

gamma doses of the background signal for various feldspars are shown in Table 1 with their sensitivity.

2) Variation of glow curve with gamma-ray doses

As a typical example, the glow curves for microcline I are shown in Figs. 4 and 5, which are recordings of the samples irradiated by ^{60}Co gamma rays over a range of $5 \times 10^2 \sim 2.5 \times 10^5$ r. It is noted that only the first peak (140°C) is generally enhanced with gamma-ray dose. About the second peak (230°C), the peak is obscure in the dose level of 1×10^4 r. This fact suggests that the 140°C peak may be useful for the accident dosimetry, considering low intensity of the natural glow signals concerned. The variations of the peak height with gamma-ray doses are shown in Figs. 6 and 7. The peak-height response for the radiation dose is linear till about a dose of 5×10^4 r.

As an extraordinary sample, the glow curves for albite I are shown in Fig. 8, where the results for the gamma-ray irradiation over the range of $5\times10^2\sim1\times10^4$ r are recorded. In this sample the broad glow maximum at about 160°C is enhanced in the dose level of 1000 r and the 140°C peak, which has been indistinguishable in the doses of this order, can be observed in the doses of 1×10^4 r. From the shape of this broad glow maximum, it is found that the glow maximum is double peaks which are composed of the 140°C peak and the 170°C peak.

IV. CONCLUSION

It has been found by the present experiment that the thermoluminescent properties of the crystals of natural feldspar have identical figure with that of feldspar separated from sands and soil. When the samples were irradiated with the ^{60}Co gamma rays, they exhibited the 140°C peak, where intensity of background signal is low. This peak increased linearly with dose. It was testified by this fact that the 140°C peak of the crystals of feldspar was also desirable for accident dosimetry. The intensity of the background signal which would restrict this dosimetry were $18\sim100$ r, as shown in Table 1, for the feldspar used in measurement. The fadings which had to be taken into consideration for the glow peak to be used for accident dosimetry were 8% per day and 3% per week in the rates of decay for the 140°C peak.

Many problems still remain to be solved in feldspar thermoluminescent dosimeter, but it was concluded that feldspar was a useful substance for accident dosimetry.

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